Automatic method to segment the liver on multi-phase MRI

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1 Purpose

The detection and characterization of hepatic lesions is fundamental in clinical practice, from the diagnosis stages to the evolution of the therapeutic response. Magnetic resonance is a usual practice in the localization and quantification of hepatic lesions [1]. Multi-phase automatic segmentation of the liver is illustrated in T1 weighted images. This task is necessary for detecting the lesions. The proposed liver segmentation is based on 3D anisotropic diffusion processing without any control parameter. Combinations of edge detection techniques, histogram analysis, morphological post-processing and evolution of an active contour have been applied to the liver segmentation. The active contour evolution is based on the minimization of variances in luminance between the liver and its closest neighborhood.

2 Method

In this paper, we propose, as part of the success of automatic liver segmentation, the application of a 3D anisotropic diffusion for the processing of MRI abdominal images. The application of a non-linear diffusion filter on an image in grey levels, generates another processed image, as a solution of the diffusion process with Neumann and initial contour conditions. We can choose a family of uniparametric diffusivities without any control parameter [5]. It is characterized by a combination of direct diffusion along the tangential component to the level curve and inverse diffusion along the normal direction. The diffusion process enhances the edges, in a wide variety of slope ranges, and smoothing the homogeneous areas.

2.1 Coarse segmentation

Once the volume of interest has been defined by the radiologist, where the liver is located, we can proceed to the 3D diffusion process above mentioned. The resulting image shows enhanced edges and smoothed homogeneous areas. From the histogram analysis of the filtered image, we obtain a low and a high threshold which are capable of defining the liver tissue. However, the multiplicative noise which appears in the MRI signal requires thresholds which are relatively unrestricted, producing an overlapping of tissue with the hepatic vascular system and other adjacent organs. A Canny detector is used to detect close contours on the filtered image. Next, the performance of morphological filtering in the threshold image and contour detection image reduces the object of the liver, preserves the shape of the liver, and detects the initial liver region. To reduce the noise and detect the coarse liver region, we perform on the region-labeling algorithm. Since the liver is the largest organ, we can select the first approximation of its segmentation. After this first splitting of the image, a part of vascular system is outside the course segmentation and the liver contour in each slice is blurred and inaccurate. Starting with this first solution, an active contour is evolved in order to obtain the final segmentation.

2.2 Fine segmentation

The liver course segmentation contains mainly parenchyma. A large part of the hepatic vascular system, the external musculature and the right kidney are left outside. The starting hypothesis for refinement is based on the fact that the closest neighborhood has lower intensity than the liver. This statement is true in the protocols which are used for hepatic lesions detection and that are based on 3D axial dynamic analysis. The contour will evolve inside the liver with an average growth in intensity when it adds the vascular system. Therefore, the intensity variability inside the liver will increase, and must be neutralised by external variability close to the liver. We propose to apply a simplified Mumford-Shah functional. The objective is the minimization of internal and external variance in luminance with respect to the partition of the contour together with minimization of the contour [2].

3 Results

The FSPGR sequence was used in the T1 weighted images of the patients and the breath-hold protocols were followed in order to eliminate the movement artefacts. ITK was used to develop the algorithms and clinical practice was conducted with the necessary modifications in ITK-Snap, we call it *Liver-Segm.* In the diffusion process, the unlimited diffusivity when the gradient module approaches infinity has been resolved by using a small regularization constant ε. We have used the value of 10^{-3} in the experiments. The AOS algorithm has been used to resolve the semi-implicit scheme [6]. The images have been filtered with a single iteration with a time increment of $0.01s$. The use of level set

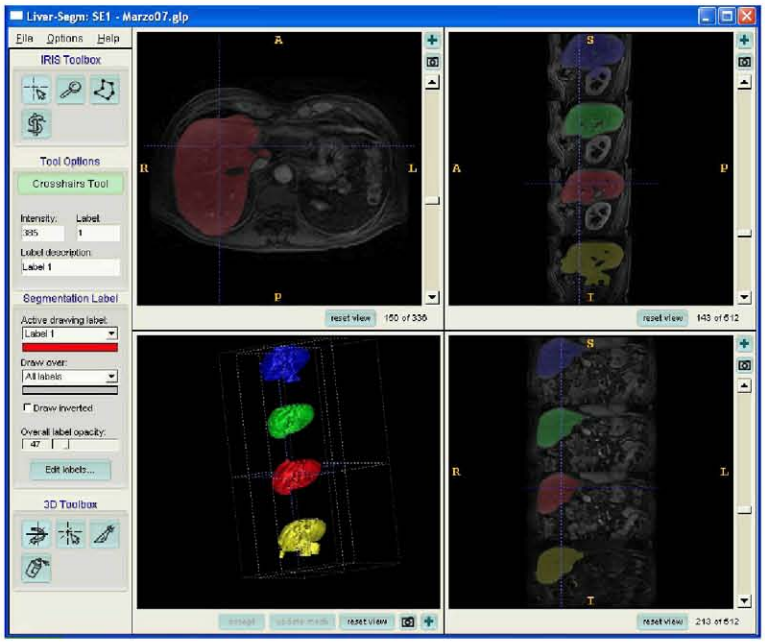

Figure 1: GUI LiverSegm

techniques for active contour implementation has become very popular, due to its handling of points presenting discontinuities and the possibility of topological change. However, the numerical stability problems of the dynamic and their high computational cost place important limitations in practice. Recently, a new method, included in the narrow band techniques, allows the elimination of the re-initialization stages, reduces the bandwidth to a $3x3x3$ environment and uses a simple scenario of finite differences [3]. It is based on the addition of a term of preservation of the signed distance function in the narrow-band. Moreover, the initialization of the contour may be based on a binary image, allowing the integration of classic processing and segmentation techniques as initial solution. The active contour computational cost is reduced at least in two orders of magnitude.

The computational cost for a volume of 350x250x55 pixels is 28 s., for diffusive filtering, thresholding and post-processing, and 6 s. for evolution of the active contour. To validate the segmentation result, we compute the undirected partial Hausdorff distance [4] between the boundary of the computed segmentation and the boundary of the manual-segment ground truth. The result was 2.3 mm for 95% percentil and 2.8 mm for 99%.

4 Conclusion

We have presented a liver automatic segmentation algorithm on multi-phase MRI. First, we apply a 3D anisotropic diffusion for image enhancement. The course segmentation is obtained by a combination of edge detection techniques, histogram analysis and binary morphological post-processing. An active contour is applied for refining course segmentation. It is based on the minimization of variances in luminance between the liver and its closest neighborhood.

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